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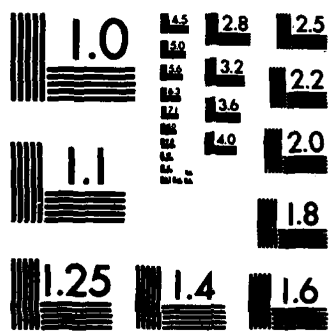
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AD-A135 598

A COST PREDICTION MODEL FOR
ELECTRONIC SYSTEMS FLIGHT
TEST COSTS

Thomas J. DuPre', First Lieutenant, USAF

LSSR 108-83

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

A COST PREDICTION MODEL FOR ELECTRONIC SYSTEMS FLIGHT TEST COSTS

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Emphasis on improving service cost estimates continues to receive high Department of Defense priority. The purpose of this study was to develop a cost estimating model that would predict flight test costs for electronic systems during early phases of a program's development. It was found that a significant cost estimating relationship (CER) exists between costs and the characteristics of the flight test design. Using a data base collected from the 3246th Test Wing, Eglin Air Force Base, a CER was developed using a multiple regression process. Statistical and logical tests were performed in order to determine the validity of the model. The CER developed may be used as an estimating tool for future budget preparations for flight testing electronic systems.

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A COST PREDICTION MODEL FOR ELECTRONIC SYSTEMS FLIGHT TEST COSTS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Systems Management

By

Thomas J. DuPre', BS
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CHAPTER 1

INTRODUCTION

A major issue in the development and acquisition of military systems is cost, whether it be cost to develop, cost to buy, cost to support, or cost to maintain (5:6). Estimating costs of proposed systems takes on increasing significance as the Department of Defense (DOD) has consistently underestimated the cost of major weapon systems (8:105). Accuracy and realism of weapon system cost estimates are prerequisites for the efficient functioning of the Defense Systems Acquisition Review Council (DSARC), an advisory body to the Secretary of Defense on all major defense systems, acquisition programs and related policy. At each major program decision point, all aspects of the program are reviewed by the DSARC. Accordingly, emphasis on improving service cost estimates continues to receive high DOD priority. In this effort the Secretary of Defense Cost Analysis Improvement Group (CAIG) was formed to exercise the dual function of reviewing service cost estimates for the DSARC and fostering defense-wide improvements in military cost analysis capabilities (14:7).

Decisions to undertake specific development projects

depend critically upon the estimates of development and production costs and to the extent that cost estimates for planning are wrong, the decisions to undertake specific projects are questionable. Further, once a decision is made to start a specific development project, cost estimates play an important role in selecting contractors and monitoring contractor performance. Being able to identify overly optimistic cost estimates and to provide incentives to control cost during development and production are important elements of the government acquisition process. Both depend heavily on the quality of cost information (15:7).

In the development phase of electronic systems the methods used to predict test and evaluation (T&E) or more specifically flight test costs need to be constantly updated and improved. During the test program formulation process, program managers must consider many budgetary aspects in establishing funding for their respective T&E efforts. When a program office requires support from a test center, a Program Introduction Document (PID) is submitted to the Responsible Test Organization (RTO). The PID is a scope setting document describing the program, identifying the known test support requirements, forecasting events, and specifically spelling out the program requirements. It is used by the RTO for basic support planning and as a basis for determining test center resources or new capabilities requirements (17:86).

Upon receipt of the PID the RTO begins preparing a Statement of Capability (SOC). This document provides a preliminary statement of the support the user may expect and the resources needed to satisfy the program requirements. It delineates the responsibilities between the RTO and the user, including the provisions of resources and the listing of program constraints (16:86). Along with this procedure the program office develops a Test and Evaluation Master Plan (TEMP). This document presents the overall system description, operations and maintenance concepts, program objectives, areas of risk, required test assets, and program responsibilities (2:II). These reports are the basis for budget submissions for both the test center and the program offices.

Direct cost funding requires that test peculiar costs associated with a particular test program be reimbursed by the program office to the designated test center. The cost associated with special instrumentation, operation of test resources (e.g., test aircraft, range operation), overtime, civilian salaries, travel and per diem, transportation and communication equipment are examples of the types of cost that may be charged a user (3:p. 10-3). Since the program office will be paying for the work performed, it needs to obtain an estimate from the test center as to how much the work will cost. This means defining the test requirements and getting together with the test center personnel some two years in advance of the actual

work. The long lead time necessary for budgeting procedures of direct cost funding makes it difficult for program offices to specifically define the requirements of the test (17:86).

Problem Statement

Estimating flight test costs for electronic systems using current procedures (detailed estimating), generally requires a well defined program. During early phases of Research, Development, Test and Evaluation (RDT&E), this level of detail is often not available. In many cases the program office has been unable to sufficiently define test requirements two years in advance as mandated by the budget process. Even though sufficient data is not available for a detailed estimate some type of cost figures must be included in the budget. If the user is truly unable to determine his long lead time requirements, the cost estimate degenerates to a "best guess" or expert opinion approach (5;17:34). Currently, there is not a cost prediction model to estimate flight test direct costs for electronic systems to aid in budget preparations.

Background

The scope of a test program covers the development process from the conceptual phase through the production decision and beyond. The initial phase of testing, defined as Development Test and

Evaluation (DT&E), is conducted to demonstrate that the engineering design and development process is complete, design risk has been minimized, and the system meets engineering and operational specifications. The second area of testing is Operational Test and Evaluation (OT&E), which is normally conducted in two phases. Initial Operational Test and Evaluation (IOT&E) is conducted to provide, before the first major production decision, a valid estimate of expected system operational effectiveness and suitability. Follow-on Operational Test and Evaluation (FOT&E) is conducted as necessary during and after the production period to refine the estimates made during the IOT&E. The system is reevaluated to ensure that it continues to meet operational needs and retains its effectiveness in a new environment or against a new threat (3:p. 10-3).

Flight testing of an aircraft or other systems by actual flight is planned to achieve specific test objectives and gain operational information (21:298). Fundamental purposes of flight testing are:

1. To determine the actual characteristics of the machine (as contrasted to the computer or predicted results).

2. To provide developmental information.

3. To provide research information (4:II).

The major problems encountered in flight testing work include:

1. Measurement of the actual values obtained during the test.

2. Determination of what the measured values would have been under some arbitrary set of standard conditions.

3. Designing of the test program to provide the desired results for the least cost in time and money within the limitations of available manpower and equipment (4:III).

As stated earlier, flight tests are used to validate predicted results. As an example, the high cost of air launched guided missiles makes it virtually impossible to demonstrate release characteristics at all combinations of aircraft angle-of-attack, release mode, normal load factor, flight path angle and carriage locations throughout the speed/altitude release envelope. Current practices call for comparison of wind tunnel based predicted trajectories with actual in-flight separation characteristics at predetermined buildup and demonstration flight conditions. If the analytical techniques are considered validated and satisfactory correlation is obtained, flight characteristics can be documented by less expensive computer analysis. If, however, correlation is not satisfactory it then becomes necessary to perform sufficient drops for comparison with the analysis until an acceptable confidence level is achieved through the update and refinement process based on actual in-flight data. The success of the entire procedure is contingent on the accuracy and reliability of both the aerodynamic prediction technique and the flight test data reduction process to minimize the number of drops and flights required in

establishing safe and operational clearance envelopes (18:p. 1-2).

The introduction of electronic data processing to general flight test operations has fostered the development of new methods of analysis as well as simply mechanizing old accepted methods. Computer oriented data systems of various size and complexity have become a necessary tool for collection and verification of test results. For the Rockwell B-1B test program performance, data handling and processing start with over 90 million data points per flight. There are more than 1900 parameters recorded at least four times a second, many of which are recorded sixty-four times a second. Multiplying this by an average flight time of seven to eight hours results in a tremendous mass of raw data (12:p. 14-2). Computer programs are designed to identify aircraft stability and control from dynamic flight test data. Modern high speed digital computers are employed which reduce cost and flow time of flight data analysis.

The major Air Force testing centers are faced with the challenge of developing sophisticated analytical techniques and safe, productive flight test methods for today's complex weapon systems. After the requirements for flight test have been set, the flight test engineer will have to organize the testing. The engineer defines the test to be executed, how many aircraft will be used for the test, the time schedule, the sequence of the tests, the test procedure for each specific test, and the location where the test will take place (1:7).

Air Force flight testing is done at the following bases:

Edwards AFB, California

Eglin AFB, Florida

Hill AFB, Utah

Patrick AFB, Florida

Vandenberg AFB, California

The cost of a flight test is composed of several items. The relative amounts of each of these items depends on the amount of existing equipment and the type of testing being done. The operation of the aircraft during the flight test will constitute a significant part of the test budget. Experienced test pilots, flight engineers, ground crew, and support are required for test flights. Other costs include:

1. Cost of the flight test definition and planning.
2. Flight test instrumentation composition cost.
3. Data processing hardware composition cost.
4. Flight test instrumentation installation and checkout cost.
5. Data processing software composition and checkout cost.
6. Flight test instrumentation operation cost.
7. Data processing cost.

The task of the RTO is to design the equipment, software and procedures to execute the flight test at minimal cost (1:12).

Literature Review

Previous studies done in this area concentrated on techniques to predict the flight test costs for new airframes and not for new electronic systems installed on an already existing aircraft. The Air Force Flight Test Center (AFFTC), at Edwards AFB, is concerned with estimating cost of flight tests and they have developed a technique for their own use. This approach separates costs into two components: variable costs, or costs allocated directly to flying hours, and fixed costs, or the sustaining manpower and other services necessary to support flight testing other than direct flying efforts. To use this procedure requires an estimate of test aircraft flying hours and total flight tests duration in months. The flight test estimate is the combination of program duration in months times the average monthly program fixed costs plus the prime mission aircraft flying hours times the variable cost per flying hour (7:3). This estimate relies on an accurate prediction of the necessary resources (monthly program costs) needed in the test which may be difficult for new airframes.

Another approach, developed by Rand Corporation, is to use the parametric method. Parametric cost analysis uses estimating relationships developed from historical program costs as a function of variables such as physical and performance characteristics (21:

511). The Cost Estimating Relationship (CER) included data from fifteen fighter, eight bomber and transport, and seven attack aircraft. The best relationship included empty weight, speed, and number of test aircraft as the explanatory variables. This study concentrated on testing of aircraft airframes and did not include the testing of other systems (11:92-96).

Another parametric study was done by the Directorate of Cost Analysis, Aeronautical Systems Division (ASD). This study computed dollars per flying hour by dividing test aircraft flying hours into total flight test cost. To develop a CER, the parameters considered were gross take-off weight, average sortie length, test aircraft flying hours, and maximum design speed. The aircraft involved in the study were the F-15, F-16, A-10, and the B-1. Only gross take-off weight was included in the equation as use of multiple regression techniques were precluded as a result of the small sample size (6:1-3). Again, this study dealt with airframe testing.

Lockheed-Georgia Company also used a parametric technique to estimate flight test costs for the Advanced STOL Transport Aircraft. Data from the C-130, C-140, C-141, YC-130 and C-5, along with available data from a number of other aircraft developed by other manufacturers was included in the data base. Explanatory variables included empty weight, maximum cruise speed and number of test aircraft. This study concentrated on transport airframe

testing (13:APPENDIX II).

Scope and Limitations

This project will deal with developing a cost prediction model for flight testing electronic systems. As seen by the literature review results, no efforts to estimate avionic or electronic system flight tests have been documented. Predicting flight testing requirements and costs is more difficult in this area because there are large numbers of multi-varied electronic systems/subsystems with non-major program status. These systems require dissimilar aircraft (e.g., F-16, F-15, A-10, F-4) to support required flight test environments.

Research Objective

The objective of this research is to develop a cost prediction model for electronic systems flight test direct cost or cost change to the user. This model could then be used by program office personnel as an aid in budget preparations.

Research Questions

Answers to the following questions will provide the means to fulfill the research objective.

1. What costs are included in flight testing of different

systems?

2. What are the significant cost drivers in developing an estimation model for flight test costs.

3. How can these cost drivers be best related to accurately predict future flight test costs.

CHAPTER 2

METHODOLOGY

General Overview

The objective of this research was to develop a cost prediction model for electronic system flight test costs. This model was a cost estimating relationship (CER) describing a numerical relationship which is useful in computing estimated costs. These estimates will be made during early phases of the program when the details are not well defined. Due to the nature of the problem a parametric cost model resulting from multiple regression techniques will be used. A simulation was not done because the level of detail in the data was not available. A recent study within the DOD discussed the merits of the parametric approach. During the early phases of the acquisition process, only limited information is available, so considerable uncertainty surrounds both this information and whatever planning data is available on how the new system will be developed and produced. Nonetheless, cost estimates must be made. Both the fact of limited and uncertain information on which to base estimates, and the use to be made of these estimates, strongly suggests the employment of parametric estimating procedures (9:2).

For most new systems the parametric approach is the best method that can be used to make an estimate from the limited information available during concept formulation, i.e., when only mission and performance requirements are defined. Furthermore, parametric methods provide the analyst with an inexpensive means of examining the impact on cost of a variety of changes of system performance requirements. In short, the parametric approach is based upon aggregate relationships between costs and the physical and performance characteristics of the system under study. These relationships are derived from related historical data, following the principles of statistical inference (9:2). Other, less desirable, cost estimating methods useable during the same time period are those called expert opinion and analogy.

The parametric method has limitations that must be considered. To be fully effective, it requires an extensive base of past cost and performance data. Its use implies that the relationship that existed in the sample on which the estimating equations were based, will continue to exist in the future. Extrapolations which involve systems with a large advance in the state-of-the-art become more difficult as the new program differs more and more from the technology which existed at the time the sample programs were procured. The technique can only be used as a base estimate to which adjustments are made to allow for the non-applicability of past experience

(20:4).

Data Collection

Variables to be Considered

The parametric model development was centered on the characteristics of the test effort. The dependent variable used in this study is direct cost of flight test (those costs the SPO must reimburse to the RTO) measured in total program dollars. The independent variables consisted of potential cost drivers. Estimators are continuously searching for combinations of aircraft characteristics that will provide consistently reliable estimates and be logically related to cost. The potential cause and effect relationship between each potential cost driver and the dependent variable was evaluated to determine a logical link. Only then can a potential cost driver be considered as a candidate for inclusion in the model. This process of identifying the determinants of flight test costs for electronic items relied heavily on the knowledge of people in the field. Some cost drivers believed to effect the cost of flight test include number of sorties, test aircraft flight hours, length of program, and the type of aircraft (7:4). These performance characteristics deal with the test design and not characteristics of the electronics system being tested.

A restriction in the process of identifying cost determining parameters is that the parameters must be available. There are

two aspects of this availability:

1. The parameter should be one which is specified early in the life cycle and does not require completion of the design of the test before it is known.

2. The parameter should be easily and unambiguously measurable (9:20).

Prior to incorporating data within the postulated estimating relationship, it must be consistently defined. Aside from uniform definitions of just what costs are included within the recorded expenditures, several required considerations ensure that costs are displayed in consistent and comparable terms. These include the effects of (1) year-to-year price level changes, (2) productivity or manufacturing technology changes, and (3) "learning" or cost quantity effects upon production costs (9:26).

Data Search

Data on the individual systems flight tested was gathered from the individual program offices located at Wright-Patterson Air Force Base. Data was also collected from the 3246th Test Wing located at Eglin Air Force Base as most electronic system testing is done there.

<u>Developing the Model</u>

A multiple regression was formulated using the Statistical Package for the Social Sciences (SPSS). All the variables were forced into the equation to see their relative effect on the model. The least squares method of regression analysis provides the best unbiased estimator of the dependent variable, therefore, this method was used. The general form of the multiple regression model is:

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + \ldots B_{n-1}X_{n-1} + E$$

where:

Y is the dependent variable representing the flight test costs.

X_i's are the independent variables representing the various flight characteristics.

B_i's are the unknown parameters to be estimated by the analysis.

E is the error term.

The specific independent variables used in the model must be logically related to cost and this logic must remain consistent throughout the model development.

<u>Solving or Manipulating the Model</u>

The data was supplied to the stepwise program in order of highest range of values to the smallest. The model formulation explored quadratic terms and possible interaction terms of potential

independent variables. Characteristics which prove not to be statistically significant will be judged to determine if their expected effect on cost is sufficient to remain in the model. The resulting equations were evaluated in order to pick the best predictor.

Evaluating the Model

In evaluating the model, the relationship between the independent and dependent variables had to remain logically consistent. If an independent variable was expected to increase cost but it had a negative coefficient causing cost to decrease, it was analyzed to determine why it was behaving this way. If explanation for this behavior is not possible the variable was excluded.

Various statistical tests were performed to determine the degree to which the independent variables predicted the dependent variable accurately. These tests are discussed separately.

Coefficient of Determination (R^2)

R^2 measures the proportion or percentage of the variation in the dependent variable explained by the regression model. It is defined as the ratio (10:525):

$$\frac{\text{Variation Explained}}{\text{Total Variation}} = \text{Coefficient of Determination}$$

Its limits are $0 \leq R^2 \leq 1$. An R^2 of one means a perfect fit, whereas an R^2 of zero means no relationship between the dependent variable

and the explanatory variables (9:49). From talking to experienced analysts in this field an acceptable level of R^2 will be defined as .80 (19).

F-Test

The F-test assesses the overall statistical significance of the model. It is calculated as the ratio of the explained variance to the unexplained variance.

$$\frac{\text{Variation Explained}/k}{\text{Variation Unexplained}/n\text{-}k\text{-}1} = F$$

where k is the number of independent variables and n is the number of observations in the sample (10:548). If the calculated value exceeds the critical value (table value) at the 80 percent level of confidence the model will be considered statistically significant.

t-Test

The t-test measures the statistical significance of each individual coefficient. It is measured as the ratio of the absolute value of the coefficient to its standard error:

$$t = \frac{|b_i - 0|}{S_{b_i}}$$

When the calculated value of t exceeds the critical value (table) then the variable will be considered statistically significant (10:550). Values will be compared at the .80 level of confidence.

Additional Test

In addition to using statistical techniques to evaluate the model, a relative error calculation will be made. This calculation examined the model accuracy by comparing the prediction error as a percentage of the actual flight test costs for each historical data point used in generating the model. This relative error was calculated based on the following formula:

$$\frac{\text{Actual Test Costs - Predicted Test Costs}}{\text{Actual Test Costs}} \times 100$$

Although no specific level will be defined, this calculation can help the decision maker assessing the risk in accepting the estimate by providing a more intuitive measure of the errors.

CHAPTER 3

DATA BASE COLLECTION

Sources of Data

The data collection process began at the ASD Reconnaissance and Electronic Warfare (RW) System Program Office (SPO) to determine what programs to include in the data base. An interview with Mr. John Allen, Director of Program Control, outlined the general type of testing that could be representative of electronic system testing as well as some specific test programs. These general areas included external systems or pods attached to the aircraft, internal systems, and dispensers such as a flare that is released from the aircraft. He also provided points of contact for the specific tests that were identified.

These contacts in Program Control were mainly concerned with accomplishing test objectives and whether the total test program was within the budget. Most of the specific data easily available was the schedule or estimated effort that was needed. As an example, the AN/ALQ-131 Receiver/Processor, which is a pod attached to the F-4, had thirty sorties scheduled (figure provided by the SPO) and in actuality only twenty-four flights were used. Actual information is

available at the SPO but this data originates from the RTO. Therefore, to easily access the source of actual data and to expand the potential data base to systems not specifically supported by the RW SPO, the RTO became a source of data. Most electronic system tests are conducted by the 3246th Test Wing located at Eglin Air Force Base.

The necessary data was collected from two different areas at Eglin. The actual cost of testing the specific system was obtained from their Job Order Cost Accounting System (JOCAS). With this system program specific costs are collected, documented, and billed to the appropriate program. Each system has a designated Job Order Number (JON) consisting of eight digits. The first four digits are either the basic Air Force Systems Command (AFSC) system/project number or the appropriate code from AFSC Regulation 27-5 or Armament Division (AD) Regulation 80-1. Of the remaining numbers, digit five denotes the financial manager, digit six denotes the customer and digits seven and eight provide the sequence of the test.

Each time a person works on a project or operates a system in support of that project it is documented by the JON to allow for specific billing. These cost inputs are collected and grouped into the following categories on the billing sheet:

AIRCRAFT AND LOGISTICS
COMPUTER SUPPORT
ENGINEERING SUPPORT
RANGE OPERATION
RANGE SUPPORT
TEST MANAGEMENT
TEST REQUIREMENTS SUPPORT
AIRCREW SUPPORT
AIRBORNE SUPPORT
PHOTOGRAPHICS
ELECTRONICS
MISCELLANEOUS

For programs involving foreign government testing there are lines for military support, civil engineering support, and overhead. These costs are reimbursable to the test organization for non United States testing. In order for foreign government testing to be included in the data base, the costs listed for military support, civil engineering support, and overhead were subtracted from the total test direct costs. By doing this, the direct cost for all programs in the data base contained the elements listed on a United States test billing sheet and could be easily compared. The systems affected were PEACE SUN, PEACE FOX, and PEACE MARBLE.

The second source of data was AD's Management Information System (MIS) which contains data for past and present testing. The number of flying hours for each type of aircraft, duration of the test in months, and the number of sorties required to complete the testing were obtained. For systems that used multiple aircraft in the testing, the dominant (by number of sorties) aircraft was selected to represent

the overall system. As an example, the ALR-56 restructuring test included sixty-two flights with an F-15, two flights with an F-4C, two flights with a T-38, and one flight with an F-16. In this example it is easy to determine that the F-15 is dominant. In all the systems there was a distinct principle aircraft in the test.

Selection of Data Points

Systems considered for inclusion in the data base were tested by the Electronic Warfare (TZW), Electronic System (TZE), and Test Requirements and Programming (TZP) Divisions of AD as broken out by their organizational chart (Appendix A). More specifically, in the electronic warfare area systems were selected from both the attack and defense subdivisions. In the electronic systems area the airborne systems were included and in the requirements and programming area the subdivision electronics were included.

The following definitions apply to tests conducted at AD:

Planning Phase - The planning phase begins upon acceptance of an effort for planning purposes. At this time a letter authorizing the planning JON and identifying the eventual direct JON is transmitted to all AD agencies involved. During the planning phase a test directive will be prepared as appropriate. During this phase AD agencies are authorized to only charge man-hours to the JON. Test planning phase ends with the initiation of the active phase.

Active Phase - The active phase begins when the scheduling of the test effort is authorized. During this phase expenditure of resources is authorized. After each flight a report is completed describing the results of the mission. The active phase ends when the last test mission is complete.

Reporting Phase - The reporting phase or the preparation of the technical summary of the entire test begins the calendar day following the completion of the last test mission. No resources other than those required for data reduction, report preparation, and deposition of test related resources will be expended. The reporting phase ends when the technical report is signed.

Suspended Phase - When a test cannot be continued for a significant period of time the test will be suspended. Normally a test will not be placed in suspension unless a delay of thirty days is anticipated. This phase begins upon publication of a letter of suspension and ends upon publication of a letter placing the effort back into another phase. A suspended test may require an amendment to the test directive or an amended Statement of Capability to reflect changes in completion dates, significant test redirection, and cost changes.

Closeout Phase - The closeout phase begins upon activity completion and ends sixty calendar days later. The purpose of this phase is to allow for the final accumulation of charges which should

accrue to the test effort. After the closeout phase no further charges can be accepted under that JON.

In the areas selected systems within the last three years that were at least into the reporting phase were examined for inclusion in the data set. By including only the most recently completed systems, the effect of changing technology was kept to a minimum. Radio Corporation of America (RCA) has the contract for collecting and maintaining the data base for tests conducted by AD. No suspended programs were considered for inclusion because the uncertainty of scheduling and test objectives of a suspended system cause unexpected changes in the total cost of the system.

Of the final systems included, the breakout by division are outlined in Table 1.

Table 1

Systems Included by Division

DIVISION	NO. OF SYSTEMS
ELECTRONIC WARFARE (TZW)	
Attack (TZWA)	9
Defense (TZWD)	2
ELECTRONIC SYSTEMS (TZE)	
Airborne (TZEA)	1
TEST REQUIREMENTS AND PROGRAMMING (TZP)	
Electronics (TZPE)	3

All cost figures were collected in terms of the fiscal year they were charged and adjusted to constant 1982 dollars. The DOD raw inflation indices for RDT&E were used in the inflation adjustment process. The procedure for this process is to divide the actual fiscal year cost figure by the index for that year to convert the fiscal year dollars into the 1982 base year dollars. The index is from Air Force Regulation (AFR) 173-13, USAF Cost and Planning Factors and is listed in Table 2.

Table 2

DOD Raw Inflation Indices
as of 1 February 1983

FISCAL YEAR	CONVERSION INDEX FOR RDT&E
1980	.818
1981	.916
1982	1.000
1983	1.050

The results of the data collection process are shown in Table 3. An expanded version of the cost data appears in Appendix B.

The number of months listed only includes the time the program was in the active phase of testing. The aircraft category was determined by the direct cost of a one hour flight for the dominant aircraft in the test program. The costs per flying hour were obtained from AD's Standard Rate Pricing Catalog. These costs include base

Table 3

Results of Data Collection Process

JON	System (Division)	Direct Cost 1982 $ (000)	# Sorties	# Hours	# Months	Aircraft Class	Test Class
5615WA07	Countermeasures Subsystem (TZWD)	2535	89	127.8	8	3	1
2683WA11	Strike Shield (TZPE)	1010	51	90.8	8	4	3
2683WA12	Featured ECM Trial Phase Two (TZWA)	935	73	122.9	6	3	1
ASD0WA45	F-16 ALR-69 Improvement (TZWA)	834	57	87.6	13	2	3
5618WA11	ALR-56 Restructuring (TZWA)	828	67	103.5	25	3	3
921AWF21	ALQ 119 Lens Array (TZWA)	540	50	92.5	15	3	2
2272WA03	AN/ALQ 131 RP (TZPE)	435	24	36.7	13	3	2
ASD0WA47	A-10 ALR-69 Improvement (TZWA)	434	29	49.0	11	1	3
FDISWA01	Peace Fox (TZWA)	334	05	8.9	13	3	3
ASD0WA37	F-16 RAM Test (TZWA)	303	44	50.4	5	2	2
FDSRWA01	Peace Sun (TZWA)	189	04	7.3	6	3	3
2683WA06	Improved Strategic Chaff (TZWD)	185	25	36.6	24	3	1
FMSOWA14	Peace Marble (TZWA)	178	04	9.3	2	2	3
2274WA04	RR-180 Dual Chaff Cartridge (TZPE)	151	18	28.4	12	2	1
2000EQ12	Aerodynamic Flare Test (TZEA)	131	13	14.4	10	4	1

level maintenance and aviation petroleum, oil, and lubricants (POL) (Table 4).

Table 4

AD's Cost Per Flying Hour
FY 1983

AIRCRAFT	COST	CLASS
T-38	$ 1026.58	1
A-10	1487.34	1
F-16	2649.38	2
F-4E	4103.01	3
F-4D	4551.44	3
F-15	4595.07	3
F-4C	5298.94	4
F-111	5748.02	4

One exception was made in categorizing the Strike Shield program. Although the dominant aircraft was the F-15, over forty percent of the sorties were flown by an F-111. This program was put in a higher class (4) because of the relatively high cost of flying the F-111.

The test variable was assigned a value depending on the type of system being tested. Each system was placed in a general class as outlined by Mr. Allen (Table 5).

Data Features

Strengths

A strength of the collected data is that for each job there is

Table 5

General Class and Number of Systems in Each Class

TYPE OF SYSTEM TESTED	CLASS	# OF SYSTEMS
DISPENSERS	1	5
EXTERNAL	2	3
INTERNAL	3	7

a precise cost factor for resources used in support of that job. This is evident by the previous chart of cost per flying hour for specific aircraft. There are also factors for other resources such as for the use of range radars or photographic equipment. By using the Standard Rate Pricing Catalog the cost centers will know exactly how much to charge to a specific JON.

The costs are then collected through the JOCAS to develop the total to be billed the user. This cost collection system has been in effect since before 1980 and all the test data occurs after this date. Therefore, each system's costs were collected and documented the same way which makes them easily comparable. Also, since all of the systems were tested in the last three years the costs associated with technology changes were kept to a minimum.

Other strengths of the data were:

1. All the data is objective in nature and stated in quantitative terms.

2. There appeared to be no bias in the data from the sources from which it was gathered.

3. All numerical conversions used established DOD published rates (e.g., inflation index).

Weaknesses

Program delays caused by unsuccessful missions can cause unexpected increases in the cost. After each flight a Mission Accomplishment Report (AD Form 57) is submitted by the test engineer. This form lists the objective, results, completion status, productivity, and reasons for failure or cancellation. Some possible reasons for an unsuccessful mission include weather, test item malfunction, aircraft configuration incompatibility, aircraft system malfunction, aircraft not available due to maintenance, lack of technical support, and safety. Each day these forms are submitted to the technical advisor to the Commander for Test Engineering who determines if the flight, all or nothing, should be charged to the user. If cancelled by weather or an AD aircraft or system malfunction, the Test Wing will absorb the costs. The cost recorded are for successful missions and missions where the customer item (test item) malfunctioned. The level of delays or extra flights needed to meet the test objectives is absorbed in the total cost charged to the user. All costs charged to the user are included in the data base.

There are no provisions distinguishing between programs that were completed on schedule and those that incurred delays.

Another weakness in the data is that some of the programs are still in the reporting phase. As stated earlier, no resources other than those required for data reduction, report preparation, and deposition of test related resources will be expended. All flying, range operation, and engineering activities, which are the major contributors to the costs, have been completed by this time. Some computer support may be required to combine and analyze the data from each individual flight. The effort used to complete the final report is billed under the test management category. Six of the programs were still in the reporting phase with some closer to completion than others. The programs still in reporting were:

Countermeasures Subsystems
ALR-56 Restructuring
Improved Strategic Chaff
Strike Shield
AN/ALQ 131 RP
Aerodynamic Flare Test

When a program reaches this stage approximately 90% of the program costs have been collected and billed to the user.

CHAPTER 4

PARAMETRIC COST MODEL DEVELOPMENT

Logic of the Relationship

Prior to evaluating the model by statistical techniques, it is necessary to identify a cause and effect relationship between the selected independent and dependent variables. The development of a logical relationship allows for a guide for transforming variables as well as providing an additional check on the validity of the model.

As the first independent variable, number of flight hours, increases the cost of the flight test program will increase. This increase in cost should occur at a constant rate as AD has a factor to charge the user for each flying hour. Each hour flown will cost the same as the previous hour.

The second independent variable, number of sorties, follows the same logic as the flight hours since the user should expect to pay more as the number of sorties increase. This increase, however, should occur at increasing rate. The earlier flights are used to set up the equipment to make sure everything is working properly. In later flights the actual testing will be done. During these later test flights, when the actual mission is being simulated, more resources

will be used which will drive the cost up at an increasing rate.

As the third independent variable, length of the program in months, increases, the cost will decrease. A program that has a higher priority and takes a shorter time to complete may overwork the system. Additional resources, overtime salaries, and extra maintenance may be needed to meet the requirements of the accelerated program. Assuming the test is a significant size for the RTO the shorter time may have adverse effects of the cost to complete the test. For longer test programs, that do not place special requirements on the existing resources, the test will run more efficiently and cost less to accomplish. This decrease will occur at a linear rate over the relevant range of the data. Finally as the program continues to drag on the cost is expected to increase.

The remaining independent variables are indicator or dummy variables that classify the test into specific categories. Dummy variables are used to account for the fact that the observations within a given category are associated with one set of regression parameters, while observations in a second (or third) category are associated with a different set of regression parameters. The type of aircraft will effect the cost as some are more expensive to fly and maintain than others. The final independent variable is the classification of the type of testing being done. By distinguishing between tests, systems that have similar effects on costs can be grouped

together.

Potential Model Structures

The sample consisted of the fifteen electronic system flight test programs. The costs were assumed to be a function of the following independent variables:

Sorties

Months

Flight Hours

A, B, C

X, Y

where A, B and C represent the dummy variable for the type of aircraft and X, Y represent the dummy variable for the type of test. In using the dummy variables, whose values are either 0 or 1, the test aircraft and type of system being tested must be placed into a class. In the case of test aircraft there are four possible classes. Depending on the class, the coefficient is multiplied by either 0 or 1 to include the effects of that variable on the dependent variable. The values of the variables that correspond with each class are given in Table 6.

Table 6

Variable Values for Each
Aircraft Class

CLASS	VARIABLE A	B	C
1	1	0	0
2	0	1	0
3	0	0	1
4	0	0	0

As an example if the test aircraft is an F-16 (Class 2), a 1 would be inserted in the equation for variable B while the A and C would take on the value of 0.

In the case of the type of testing, the corresponding values for the X and Y variables are given in Table 7.

Table 7

Variable Values for Each
Test Class

CLASS	VARIABLE X	Y
1	1	0
2	0	1
3	0	0

To assign the best specification whose behavior was consistent with prior expectations the data base was input into the SPSS program and run as a linear function. The initial run was analyzed to look for specification errors by the use of net scatter diagrams.

To draw a net scatter diagram the value of the independent variable is plotted on the X axis. The net regression line for that variable is graphed (slope = b value for the specific variable from the linear run). Next the residual for each of the observations is plotted as the distance from the net regression line. The plot of residuals should appear randomly distributed about the regression line if the specification is correct. The graphs serve as a basis for decisions as to whether transformations are called for and what transformations should be considered.

The net scatter diagram for the independent variables flight hours and months had no apparent patterns. This suggests that these variables are properly specified which is consistent with the previous established logic. The graph for the variable number of sorties had a pattern suggesting a non-linear relationship.

Collinearity

A problem that resulted from this run was that the coefficient for the number of flight hours was negative. This means the first derivative of this variable is negative which violates the logic or

expected behavior for this variable. This result can be caused by the relatively small size of the sample as there is always a chance of getting unexpected outcomes. Another explanation for this problem is the existence of collinearity between this variable and the number of sorties.

Collinearity occurs when there exists a relationship between two or more independent variables. In a regression model, collinearity causes instability in the results as analysis produces large variances which increases the confidence interval around the regression line. By looking at the correlation matrix, which looks at the pairwise relationship between variables, it is evident by the value of .998 that the variables flight hours and sorties are very strongly related. The reason for this is that the sample consists mainly of fighter aircraft and for these types of aircraft the sortie length normally falls between one and two hours. Each mission flown will add approximately the same number of flight hours to the total of the test flight hours.

To reduce this collinearity, other than increasing the sample size, the related variables can be combined to form a new variable or one of the variables can be eliminated. By dividing flight hours by sorties a new variable, defined as average sortie length, was created and included as one of the independent variables. The number of sorties remained in the equation while the number of flight

hours was eliminated. This particular combination was chosen because it still measures the same theoretical characteristics (flight hours) and is related to costs. This new variable would have a positive effect on costs as the length of the sortie increased the cost should increase. This increase, however, should occur at a linear rate because of the set flying hour costs.

Average sortie length was included in the model and the equation was again run as a linear function. The new variable and number of sorties were not highly correlated as the value from the correlation matrix was -.218. An additional test for collinearity that goes beyond pairwise correlation is the tolerance test. Tolerance is defined as $1 - R_i^2$ where R_i^2 is the coefficient of determination when one independent variable is regressed against the remaining independent variables. A high tolerance value (close to one) means a low correlation. The tolerance values were in Table 8.

Table 8

Tolerance Levels for Each Variable

SORTIE	.777
AVERAGE SORTIE LENGTH	.425
MONTHS	.723

Generally, if one or more of these values is approximately the same size as the R^2 from the regression equation then multicollinearity is a problem. In other words, if the strength of the association among any of the independent variables is approximately as great as the strength of their combined linear association with the dependent variable, then the amount of overlapping influence may be substantial enough to make the interpretation of the results difficult and imprecise (10:563). In the worst case 57.5 percent of the value of average sortie length can be explained using the remaining variable (as compared to over .80 for the linear run with the dependent variable). By creating the new variable average sortie length the collinearity in the model was reduced and no longer was causing adverse effects on the model.

Outliers

The data set was analyzed for outliers and to determine if these outliers were influential. The computer printout listed the studentized residual values for the data points that were potential outliers. These values are compared to the t distribution value with 6(n-k) degrees of freedom and a confidence level of .90. This confidence level was chosen as it is a standard level used in statistical analysis. This procedure revealed that the first and third data points entered were outliers. The way to determine if these outliers are

influential is with "Cook's Distance" which is also printed on the computer output. This method compares values with critical values of the F distribution with k and n-k degrees of freedom. If the calculated value is in the tail, it is considered to be influential. At the 90% level of confidence the critical value was 2.55 which was greater than the calculated value from both the first and third data points. Therefore, although there were outliers they were not influential at the 90% level.

The observations that were identified as outliers included the Countermeasures Subsystems program and the Electronic Countermeasure (ECM) Trial Phase Two program. They were similar systems in that they flew the most sorties, 89 and 73 respectively, in a relatively short period of time. Both programs had at least 6% of the total cost listed as miscellaneous expenses that are not evident on the other programs. This expense which amounts to over $156,000 in the Countermeasure Subsystem and $86,000 for the ECM Trial Phase Two, is a probable source in making these points outliers. There is no evidence of an error in recording, instrumentation malfunctioning or observer measurement mistakes. Although outliers exist there is no reasonable and consistent justification for their exclusion and at the 90% level they tested to be non-influential outliers.

After checking for collinearity and outliers, various

statistical tests were performed with the linear run to determine the degree to which the independent variables predict the dependent variable. The first test was the coefficient of determination (R^2) which measures the portion of the dependent variable measured by the regression model. The R^2 for the linear run was .83 which exceeded the accepted level of .80.

The F test, which tests the null hypothesis that there is no linear relationship at all in the population (i.e., all the B values equal zero) was set at the .80 level in order for the model to be considered statistically significant. The computed F value was 3.78 which was greater than the critical value (with eight and six degrees of freedom). Therefore, the null hypothesis was rejected and the hypothesis that the equation is useful in describing costs was accepted at the 80 percent level.

The t test was used to test the significance of the individual coefficients in the regression model. Computed "t" values were compared to critical "t" values at the .80 level of confidence. The most significant variable was the number of sorties at a level of .9966. The number of months also met the criteria as it was significant at a level of .8356. Ihe created variable, average sortie length, did not meet the set criteria and was eliminated from the model. It did little to explain the dependent variable because the data set included aircraft with little variation in the length of the

sorties. The remaining t values for the individual coefficients that made up the dummy variables were not significant but this has little meaning for the model. All the variables (value either zero or one) are used to place the aircraft and test into the proper category. These single variables have little meaning when they are alone but need to be taken as a set to add meaning to the model.

With the variable average sortie length eliminated, the equation was again run as a linear function. Net scatter diagrams were drawn for the variables, number of sorties and length in months. They are shown in Figure 1 and Figure 2, respectively. The length in months appeared properly specified while the diagram for number of sorties suggested a non-linear function. Therefore, to improve on the specification of the model the number of sorties was transformed to a squared variable. A full quadratic function ($SORTIE^2 + SORTIE$) was not used because of the limited number of tests in the sample. Also, this combination was run and the coefficient for the variable number of sorties did not meet the previous set criteria, while the coefficient for number of $sorties^2$ remained significant.

Evaluating the Selected Model

In evaluating the validity of the model emphasis was given to the principle that the specific functional relationship between independent variables (cost drivers) and the dependent variable (cost)

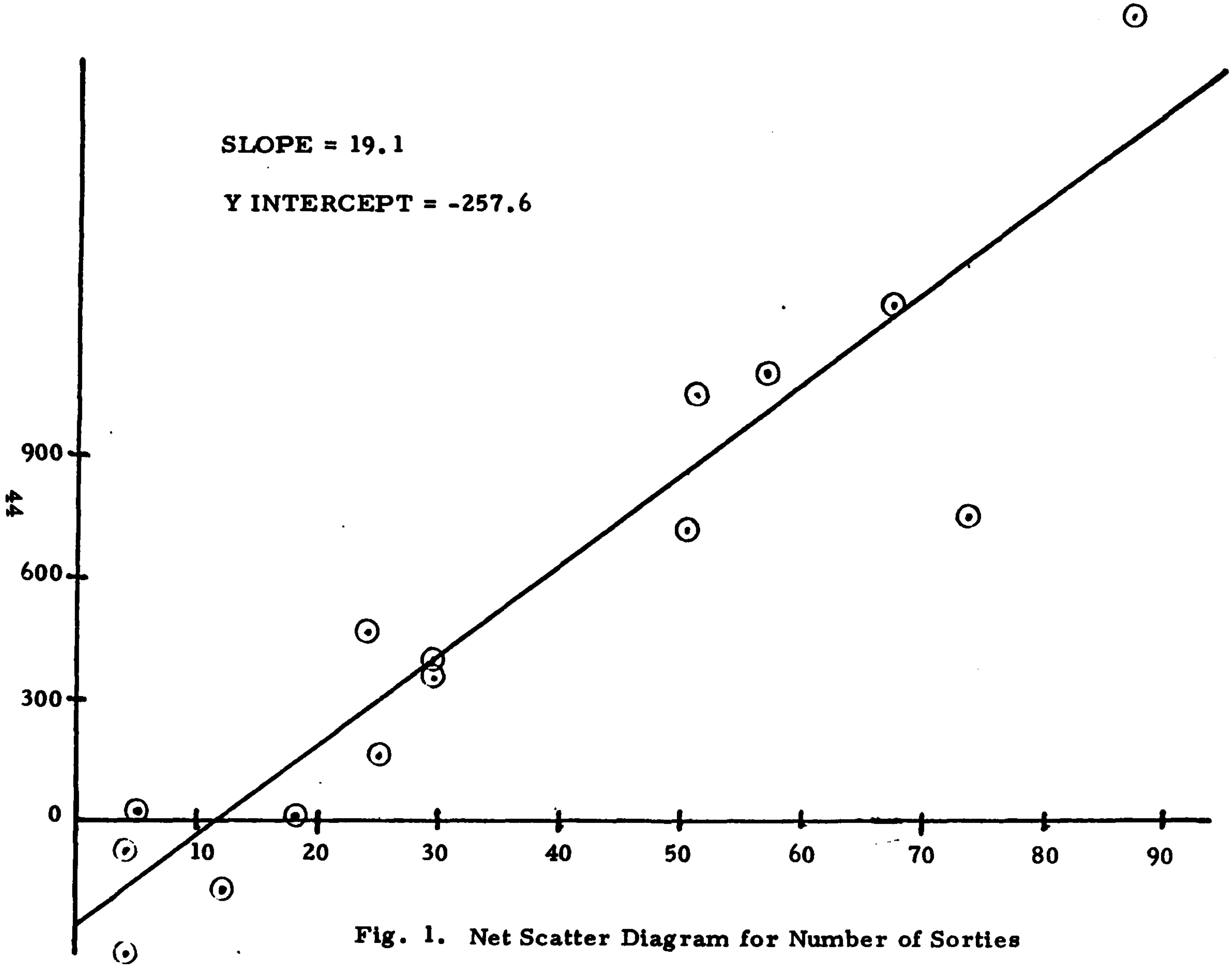


Fig. 1. Net Scatter Diagram for Number of Sorties

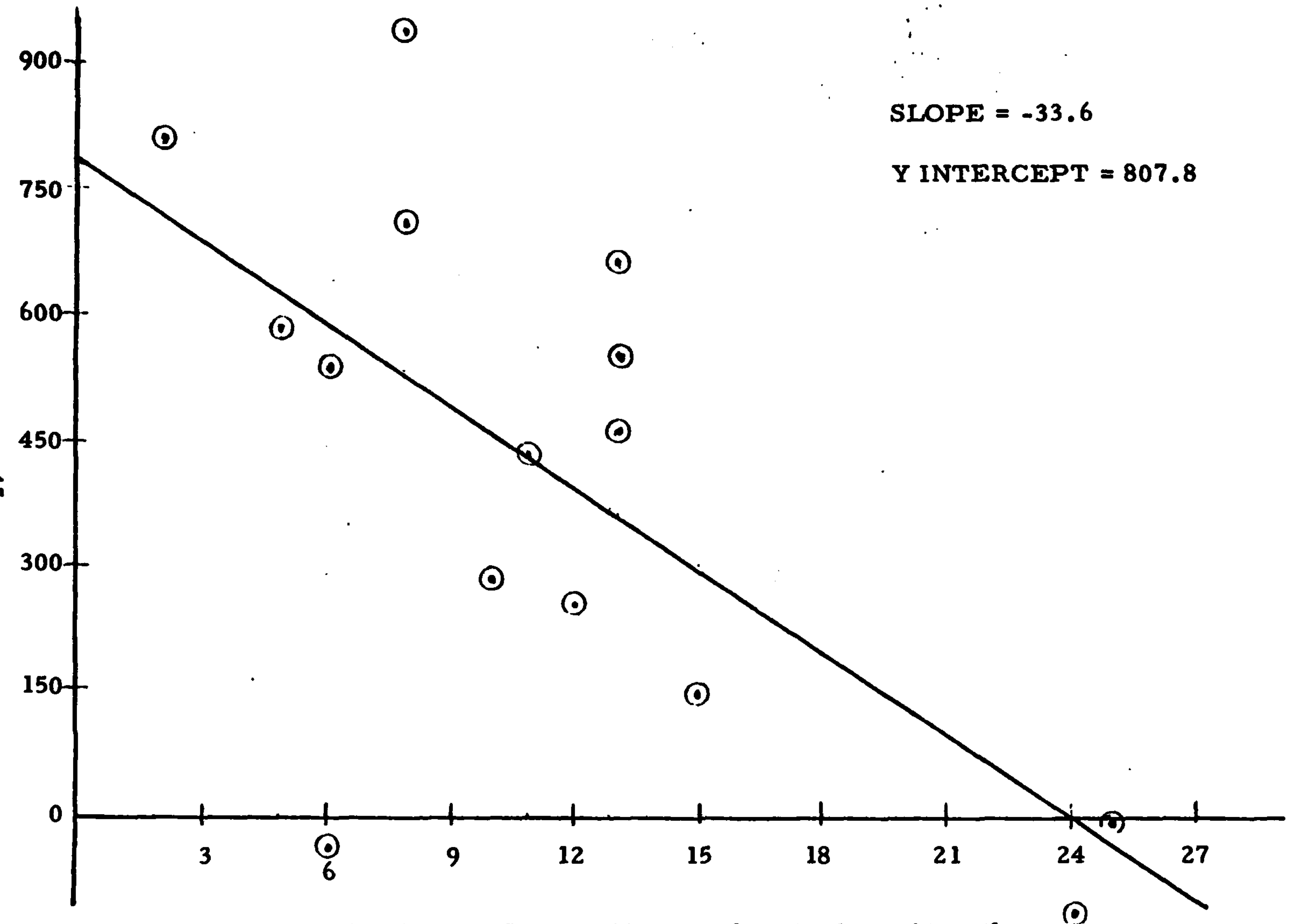


Fig. 2. Net Scatter Diagram for Number of Months

be consistent with previous expectations. After making the transformation the signs of the coefficients were checked to see if they would produce the proper first and second derivatives for that particular variable. Without the underlying logic the CER can be misleading.

The independent variable, number of sorties, was squared and the coefficient was positive. This is consistent with the expected outcome as the cost is increasing at an increasing rate with the number of sorties. The variable, number of months, was left as a linear function and had a negative coefficient.

The R^2 value increased from the linear from .834 to .881 as more of the variation was explained. The F value increased to 7.42 with a significance level of .9916 which surpasses the set criteria. The number of sorties was the most significant variable with the length in months being the next most significant.

The collinearity was at a level where it was not having an adverse effect on the model as the highest value in the correlation matrix was .645 which occurred between two of the dummy variables. The tolerance value for number of sorties and months were .83822 and .75722, respectively. These high tolerance values mean a low correlation when one independent variable is regressed against the remaining independent variables. The first data point was a possible influential outlier but there was no reasonable and consistent

justification for eliminating it.

In addition to the statistical tests a relative error calculation was made. Table 9 shows the relative error for each point estimate. This relative error calculation can be used by the decision maker to access the risk in accepting the estimate.

The results of this final run are included in Appendix C. In a final run an additional test for the proper specifications is the standardized scatterplot of the independent variables and the residual. If the specification is correct the residuals should be randomly distributed in a band about the horizontal straight line through zero. From these scatterplots both variables appear to be properly specified.

Based on the results of the logic established and the transformation performed the selected model was:

$$Y = 307.1919 + .23642\,(\#\ \text{Sorties})^2 - 17.0513\,(\#\ \text{Months})$$
$$+ 115.54565(A) - 124.83783(B) - 16.39536(C)$$
$$+ 178.66428(X) + 56.23335(Y) + e.$$

Table 9

Actual Cost Vs. Point Estimate and Relative Error

Program	Actual Cost (000)	Point Estimate (000)	Relative Error
Countermeasures Subsystem	2535	2206	.13
Strike Shield	1010	786	.22
Featured ECM Trial Phase Two	935	1448	.54
F-16 ALR-69 Improvement	834	729	.12
ALR-56 Restructuring	828	925	.11
ALQ 119 Lens Array	540	682	.26
AN/ALQ 131 RP	435	261	.44
A-10 ALR-69 Improvement	434	434	00
Peace Fox	334	75	.77
F-16 RAM Test	303	352	.16
Peace Sun	189	192	.01
Improved Strategic Chaff	185	207	.11
Peace Marble	178	152	.32
RR-180 Dual Chaff Cartridge	151	233	.54
Aerodynamic Flare Test	131	355	1.70
		Average Relative Error ---	36.2%

CHAPTER 5

MODEL USAGE AND SUMMARY

The CER developed by this thesis effort may be used to predict flight test costs for electronic systems. The cost was defined as the direct cost charged to the SPO for the RTO to complete the test. This model can be used by the SPO to make budget estimates early in the program's life. Estimates from this model will be in FY82 dollars, therefore, care should be taken in converting the FY82 dollars to the appropriate current year dollars.

The CER is used by entering values of the flight test characteristics for the system to be estimated into the model. The accuracy of the model will be partially dependent upon the accuracy of the data values used in estimating the cost of the system. Values entering the model should be checked for consistency and reasonableness in relation to existing systems in the data base.

An area of risk in the accuracy of the variable inputs is the possibility of cancelled or unsuccessful missions.

Eglin program engineers, who are in charge of making schedule and cost estimates, make provisions for such unexpected events. If ten successful missions are needed to complete the test

the programmer normally will schedule fifteen missions. This 1.5:1 ratio is the guideline for testing of systems where similar tests have previously been successful. As an example, this ratio would apply when a system was moved from one aircraft to another or when a system was updated and improved. In the event of an increase in the state-of-the-art, this ratio would increase. In the event of technological change twice as many sorties may be scheduled, and if the uncertainty is very high, the programmer may decide to move this ratio to as high as 5:1. As the uncertainty in the system and the means of testing the system is reduced, the percentage of successful flights will increase. Once the number of successful sorties needed to complete the test is determined a factor should be applied to reduce the risk of predicting the cost.

Summary

The objective of this research was to develop a cost prediction model for electronic system flight test costs. Answers to the research questions provided the means to fulfill the research objective. The costs included in flight testing are categorized and billed to the customer. These costs are outlined by program in Appendix B. The significant cost drivers in developing an estimation model for flight test include the number of sorties flown, the length of the program, the length of each sortie, the aircraft used in the

test, and the type of system being tested. These cost drivers were combined through logic and statistical techniques to form an equation to predict future flight test costs.

The research and the CER developed from this thesis effort has been done primarily to enhance and to aid the cost estimating capabilities of the Program Control Division of the Reconnaissance and Electronic Warfare System Program Office, Aeronautical Systems Division, Air Force Systems Command. The work presented relies on the assumption that the CER could be developed based on the flight test characteristics. The model developed is applicable to those systems which are from the same technological base as the systems in the current data base. To keep the model current, new data should be collected and added as it becomes available. As changes are made to the existing data, the coefficients of the variables and the variables themselves may change. Only with a continual maintenance and upkeep of the data base will the CER be able to be used as an effective tool for estimating electronic systems flight test costs over any period of time.

Limitations of the Model

The dependent variable in the model was defined as direct costs and does not estimate the total cost of the flight test effort. Also, there are no provisions to examine the impact on cost of test

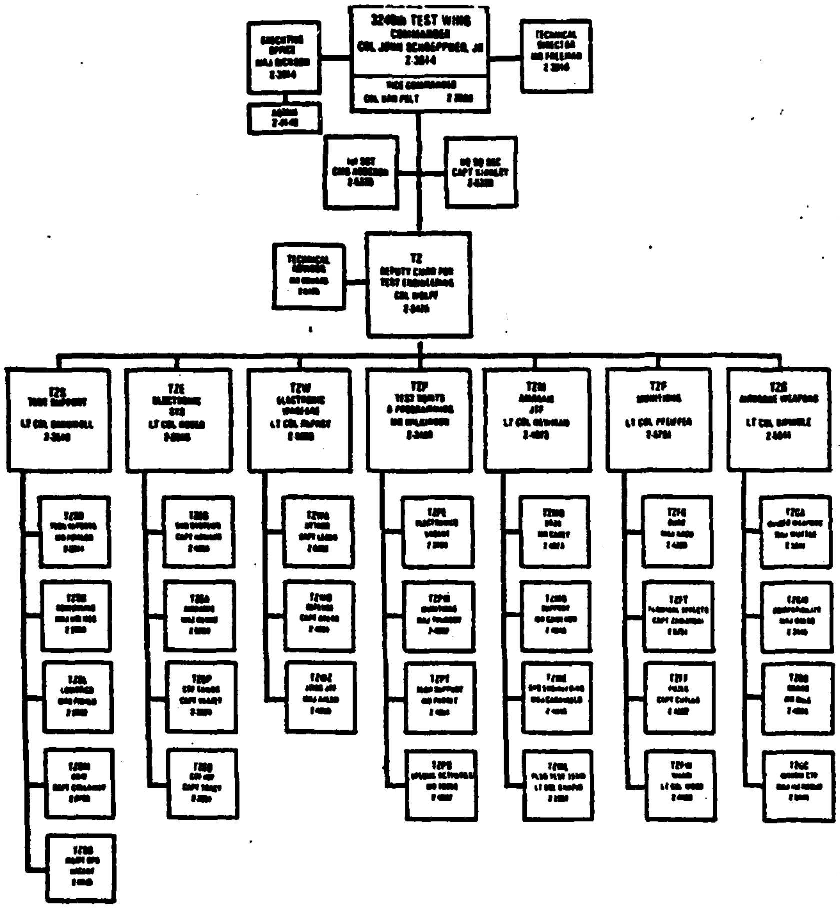
item malfunctions or program delays.

Another limitation of the model is that the coefficient for variable number of months was negative. Although reasons were given for this outcome it is not intuitively appealing in the general case. This may be caused by an inherent problem in the data base. Due to the time constraint to complete this study this problem was not further examined.

APPENDICES

APPENDIX A

ORGANIZATIONAL CHART
OF 3246TH TEST WING
EGLIN AFB FLORIDA



AS OF 15 OCTOBER 1982

APPENDIX B

DETAILED COSTS BY BILLING CATEGORY AND FISCAL YEAR

COUNTERMEASURES SUBSYSTEM
JON 5615WA07

	FY 1981	FY 1982	FY 1983
Aircraft and Logistics	104	427991	207924
Computer Support	189	118397	93351
Engineering Support	7216	976017	22656
Range Operation	----	255711	115538
Range Support	----	14100	399
Test Management	2522	58720	16989
Test Requirements Support	8879	4229	----
Aircrew Support	----	954	----
Airborne Support	----	58	37154
Photographics	----	7299	2647
Electronics	----	----	22602
Miscellaneous	751	140000	16251
Total	19661	2003476	535411

STRIKE SHIELD
JON 2683WA11

	FY 1981	FY 1982	FY 1983
Aircraft and Logistics	----	362	457614
Computer Support	624	17332	105516
Engineering Support	10918	165223	7139
Range Operation	764	63031	114812
Range Support	----	411	2113
Test Management	76	503	7329
Test Requirements Support	1275	6649	----
Aircrew Support	----	----	4026
Airborne Support	----	----	66867
Photographics	----	69	1228
Electronics	----	----	10775
Miscellaneous	----	631	481
Total	13657	254215	777900

FEATURED ECM TRIAL PHASE TWO
JON 2683WA12

	FY 1982	FY 1983
Aircraft and Logistics	546023	----
Computer Support	99217	41156
Engineering Support	65636	----
Range Operation	60639	1446
Range Support	122	----
Test Management	10677	10493
Test Requirements Support	13270	----
Aircrew Support	1269	----
Airborne Support	----	277
Photographics	122	33
Electronics	----	----
Miscellaneous	86522	360
Total	883497	53765

F-16 ALR-69 IMPROVEMENT
JON ASD0WA45

	FY 1981	FY 1982	FY 1983
Aircraft and Logistics	27225	190434	47155
Computer Support	17288	69574	19101
Engineering Support	45447	44060	6797
Range Operation	49232	223761	59085
Range Support	34	374	----
Test Management	209	2479	----
Test Requirements Support	3825	2537	----
Aircrew Support	----	----	9138
Airborne Support	----	----	10101
Photographics	----	276	----
Electronics	----	----	----
Miscellaneous	----	----	----
Total	143260	533495	151377

ALR-56 RESTRUCTURING
JON 5618WA11

	FY 1981	FY 1982	FY 1983
Aircraft and Logistics	238383	67376	23894
Computer Support	49669	46552	9612
Engineering Support	17721	1622	----
Range Operation	238332	60847	15605
Range Support	1790	----	----
Test Management	----	5594	1085
Test Requirements Support	1491	----	----
Aircrew Support	171	----	----
Airborne Support	----	----	----
Photographics	----	----	----
Electronics	----	----	----
Miscellaneous	----	----	----
Total	547557	181991	47805

ALQ 119 LENS ARRAY DT&E
JON 921AWF21

	FY 1980	FY 1981
Aircraft and Logistics	86024	146946
Computer Support	43712	20761
Engineering Support	3162	4074
Range Operation	80014	46776
Range Support	----	89
Test Management	27299	6294
Test Requirements Support	----	428
Aircrew Support	----	----
Airborne Support	----	----
Photographics	----	170
Electronics	----	----
Miscellaneous	----	----
Total	240211	225598

AN/ALQ 131 RP
JON 2272WA03

	FY 1981	FY 1982	FY 1983
Aircraft and Logistics	----	116445	49848
Computer Support	312	39113	11367
Engineering Support	----	7176	----
Range Operation	96	109092	46516
Range Support	----	----	----
Test Management	4497	28730	39313
Test Requirements Support	1536	4298	----
Aircrew Support	----	----	----
Airborne Support	----	----	357
Photographics	----	339	73
Electronics	----	----	----
Miscellaneous	----	----	----
Total	6441	305193	147474

A-10 ALR-69 IMPROVEMENT
JON ASD0WA47

	FY 1981	FY 1982	FY 1983
Aircraft and Logistics	7811	129527	1010
Computer Support	2572	29596	10060
Engineering Support	17731	47873	507
Range Operation	9353	112595	39772
Range Support	----	3325	----
Test Management	1520	703	6238
Test Requirements Support	2462	----	3111
Aircrew Support	----	----	----
Airborne Support	----	----	5616
Photographics	----	725	----
Electronics	----	----	----
Miscellaneous	924	----	----
Total	42373	324344	66314

PEACE FOX
JON FDISWA01

	FY 1981	FY 1982	FY 1983
Aircraft and Logistics	29777	72856	----
Computer Support	10794	22477	8887
Engineering Support	364	2138	10784
Range Operation	54072	96992	414
Range Support	----	----	----
Test Management	729	10987	3934
Test Requirements Support	234	313	----
Aircrew Support	435	356	----
Airborne Support	----	----	----
Photographics	----	----	----
Electronics	----	----	----
Miscellaneous	----	----	----
Total	96405	206119	24019

F-16 RAM TEST
JON ASD0WA37

	FY 1980	FY 1981
Aircraft and Logistics	8858	76683
Computer Support	9014	42167
Engineering Support	26889	18432
Range Operation	105	82999
Range Support	----	920
Test Management	944	4831
Test Requirements Support	----	556
Aircrew Support	----	136
Airborne Support	----	----
Photographics	----	----
Electronics	----	----
Miscellaneous	----	----
Total	45810	226724

IMPROVED STRATEGIC CHAFF
JON 2683WA06

	FY 1981	FY 1982	FY 1983
Aircraft and Logistics	4003	76788	36210
Computer Support	199	147	14381
Engineering Support	----	287	----
Range Operation	1171	5276	22160
Range Support	----	----	----
Test Management	5544	6134	6055
Test Requirements Support	2637	2887	----
Aircrew Support	331	2734	----
Airborne Support	----	----	509
Photographics	----	44	----
Electronics	----	----	----
Miscellaneous	----	----	----
Total	13885	94297	79315

PEACE SUN
JON FDSRWA01

	FY 1981	FY 1982	FY 1983
Aircraft and Logistics	17437	21087	----
Computer Support	639	6117	----
Engineering Support	660	647	16612
Range Operation	39428	59564	----
Range Support	----	----	----
Test Management	1852	5424	14948
Test Requirements Support	271	204	----
Aircrew Support	194	139	----
Airborne Support	----	----	----
Photographics	----	----	----
Electronics	----	----	----
Miscellaneous	----	----	----
Total	60481	93182	31560

PEACE MARBLE
JON FMS0WA14

	FY 1982
Aircraft and Logistics	34636
Computer Support	27867
Engineering Support	2485
Range Operation	106917
Range Support	----
Test Management	2398
Test Requirements Support	3792
Aircrew Support	272
Airborne Support	----
Photographics	----
Electronics	----
Miscellaneous	----
Total	178367

RR-180 DUAL CHAFF CARTRIDGE
JON 2274WA04

	FY 1982	FY 1983
Aircraft and Logistics	100390	126
Computer Support	2570	1744
Engineering Support	12572	1232
Range Operation	----	----
Range Support	----	----
Test Management	10634	4225
Test Requirements Support	7130	----
Aircrew Support	912	----
Airborne Support	----	5482
Photographics	798	----
Electronics	----	1744
Miscellaneous	2595	----
Total	137601	14553

AERODYNAMIC FLARE TEST
JON 2000EQ12

	FY 1981	FY 1982	FY 1983
Aircrew and Logistics	---	5138	56186
Computer Support	---	820	8318
Engineering Support	---	6548	436
Range Operation	---	1253	8581
Range Support	---	30	---
Test Management	493	8004	8429
Test Requirements Support	624	4330	19928
Aircrew Support	---	75	124
Airborne Support	---	---	1181
Photographics	---	738	4019
Electronics	---	---	---
Miscellaneous	---	---	---
Total	1117	26936	107814

APPENDIX C

RESULTS OF THE FINAL COMPUTER RUN

```
RUN NAME           FLIGHT TEST ANALYSIS
VARIABLES LIST     COST,FLTHRS,SRT,MONTHS,A,B,C,X,Y
INPUT FORMAT       FREEFIELD
N OF CASES         15
COMPUTE            SRT=SRT**2
NEW REGRESSION     DESCRIPTIVES/
                   VARIABLES=COST,SRT,MONTHS,A,B,C,X,Y/
                   CRITERIA=PIN(0.9),POUT(0.9)/
                   DEPENDENT=COST/
                   STEPWISE/
                   SCATTERPLOTS(*RESID,SRT)/
                   SCATTERPLOTS(*RESID,MONTHS)/
READ INPUT DATA
```

VARIABLE LIST

	MEAN	STD DEV	LABEL
COST	602.667	614.335	
SRT	1968.133	2375.939	
MONTHS	11.400	6.423	
A	0.067	0.258	
B	0.267	0.458	
C	0.533	0.516	
X	0.267	0.458	
Y	0.200	0.414	

N OF CASES = 15

CORRELATION

	COST	SRT	MONTHS	A	B	C	X	Y
COST	1.000	0.918	-0.070	-0.076	-0.240	0.265	0.150	-0.144
SRT	0.918	1.000	0.063	-0.131	-0.226	0.334	0.077	-0.144
MONTHS	-0.070	0.063	1.000	-0.017	-0.330	0.405	0.204	-0.032
A	-0.076	-0.131	-0.017	1.000	-0.161	-0.286	-0.161	-0.134
B	-0.240	-0.226	-0.330	-0.161	1.000	-0.645	-0.023	0.075
C	0.265	0.334	0.405	-0.286	-0.645	1.000	-0.040	0.134
X	0.150	0.077	0.204	-0.161	-0.023	-0.040	1.000	-0.302
Y	-0.144	-0.144	-0.032	-0.134	0.075	0.134	-0.302	1.000

EQUATION NUMBER 1.

DEPENDENT VARIABLE.. COST

METHOD: STEPWISE

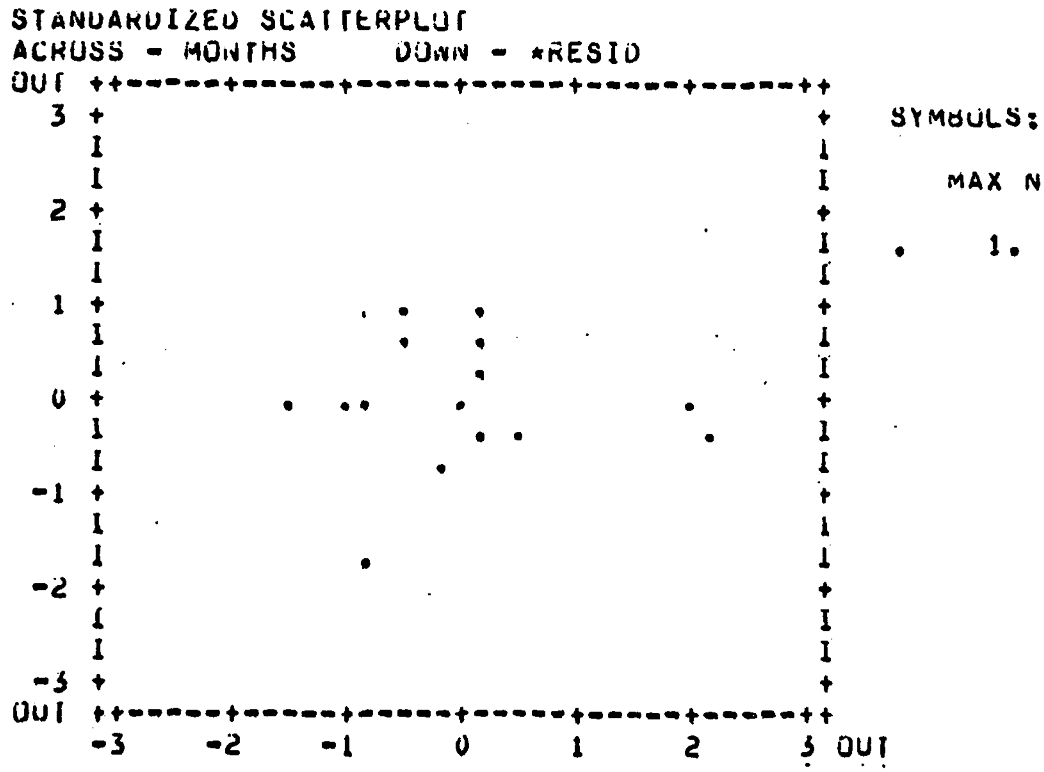
MULTIPLE R	0.93874	ANALYSIS OF VARIANCE			
R SQUARE	0.88123		DF	SUM OF SQUARES	MEAN SQUARE
ADJUSTED R SQUARE	0.76246	REGRESSION	7	4656170.30750	665167.18678
STANDARD ERROR	299.41253	RESIDUAL	7	627535.02566	89647.86081

F = 7.41978 SIGNIF F = 0.0084

----------------- VARIABLES IN THE EQUATION -----------------

VARIABLE	B	SE B	BETA	T	SIG T
Y	56.23335	213.17950	0.03790	0.264	0.7995
MONTHS	-17.05130	14.31675	-0.17828	-1.191	0.2725
A	115.54565	382.62001	0.04856	0.302	0.7714
SRT	0.23642	0.03679	0.91434	6.427	0.0004
X	178.66428	195.95041	0.13312	0.912	0.3922
B	-124.83783	265.94568	-0.09302	-0.469	0.6530
C	-16.39536	265.49237	-0.01378	-0.062	0.9525
(CONSTANT)	307.19190	260.91790		1.177	0.2775

```
STANDARDIZED SCATTERPLOT
ACROSS - SRT          DOWN - *RESID
OUT ++-----+-----+-----+-----+-----+-----++
  3 +                                     +    SYMBOLS:
    I                                     I
    I                                     I       MAX N
  2 +                                     +
    I                                     I    .     1.
    I                                     I    :     2.
  1 +             .                   .   +    *     3.
    I              .     .                I
    I                     .               I
  0 +             : *                     +
    I              .    .    .            I
    I             .                       I
 -1 +                                     +
    I                                     I
    I                           .         I
 -2 +                                     +
    I                                     I
    I                                     I
 -3 +                                     +
OUT ++-----+-----+-----+-----+-----+-----++
    -3    -2    -1     0     1     2     3 OUT
```


STANDARDIZED SCATTERPLOT
ACROSS - MONTHS DOWN - *RESID
OUT
3
2
1
0
-1
-2
-3
OUT
-3 -2 -1 0 1 2 3 OUT
SYMBOLS:
MAX N
. 1.

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